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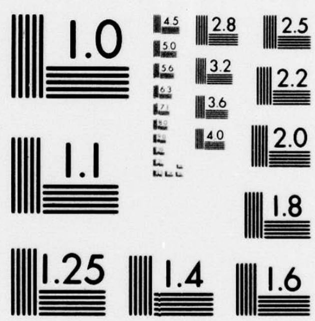

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Technical Report 389

LEVEL II

A COMPARISON OF SPEED AND ACCURACY OF INTERPRETATION OF TWO TACTICAL SYMBOLOGIES

AD A075428

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Human Resources Research Organization

ARI FIELD UNIT AT FORT HOOD, TEXAS

U. S. Army

Research Institute for the Behavioral and Social Sciences

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This report compares the speed and accuracy of interpretation of two tactical symbologies. One set of symbols was the standard set described in U.S. Army Field Manual 20-30. The other set was designed on the basis of previous research in symbology. A brief battle scenario was selected and for each symbol set 35mm slides were prepared representing updates in a tactical display. Results showed that (a) accuracy of interpretation did not vary between the sets, (b) the author-designed set was interpreted more rapidly, and (c) female participants were more rapid in interpreting the displays than male participants.

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A COMPARISON OF SPEED AND ACCURACY OF INTERPRETATION OF TWO TACTICAL SYMBOLOGIES

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Human Performance in
Field Assessment

ARI Research Reports and Technical Reports are intended for sponsors of R&D tasks and for other research and military agencies. Any findings ready for implementation at the time of publication are presented in the last part of the Brief. Upon completion of a major phase of the task, formal recommendations for official action normally are conveyed to appropriate military agencies by briefing or Disposition Form.

FOREWORD

The Fort Hood Field Unit of the Army Research Institute for the Behavioral and Social Sciences (ARI) provides support to Headquarters, TCATA (TRADOC Combined Arms Test Activity). This support is provided by assessing human performance aspects in field evaluations of man/weapons systems.

A war using modern weapons systems is likely to be both intense and short. US man/weapons systems must be effective enough, immediately, to offset greater numbers of enemy weapons systems. Cost-effective procurement of improved or new combat systems requires testing that includes evaluation of the systems in operational settings similar to those in which the systems are intended to be used, with troops representative of those who would be using the systems in combat. The doctrine, tactics, and training packages associated with the systems being evaluated must themselves also be tested and refined as necessary.

This report presents the results of an investigation of the use of two alternative symbol sets to simulate the display of changing battlefield situations. Subjects' response time and accuracy scores were analyzed for differences between the two symbol sets. The study specifically addressed the problem of recognizing and reporting changes utilizing different symbologies.

ARI research in this area is conducted as an in-house effort, and as joint efforts with organizations possessing unique capabilities for human factors research. The research described in this report was done by personnel of the Human Resources Research Organization (HumRRO), under contract MDA907-78-C-2017, monitored by personnel from the ARI Fort Hood Field Unit. This research is responsive to the special requirements of TCATA and the objectives of RDTE Project 2Q763743A775, "Human Performance in Field Assessment," FY 1978 Work Program.

Joseph Zeidner

JOSEPH ZEIDNER
Technical Director

A COMPARISON OF SPEED AND ACCURACY OF INTERPRETATION OF TWO TACTICAL SYMBOLOGIES

BRIEF

Requirement:

The work described in this report is that originally referred to in paragraph 4(3) of the Statement of Work dated 14 March 1978, under the title, "Symbology for Automated Graphic Displays." Army authorities generally agree that the traditional tactical symbols are not optimal for automated graphic tactical displays. However, despite a considerable research expenditure, a new generally acceptable symbol set has not been devised. As a result, the Combined Arms Concept Development Agency requested that studies be accomplished to compare the "efficiency" of alternative symbol sets. This effort was mounted in partial response to that request. The objectives which guided this research were:

- To determine whether symbols which were judged to be highly discriminable in other settings would prove to be so in tactical displays.
- To determine whether redundant (color plus shape) coding of symbols improved efficiency in information-processing involving tactical displays.

Procedure:

Two sets of equivalent displays depicting a battle scenario were developed. One set contained the traditional symbols and the other contained an experimental set. Each participant viewed only one set, and was asked questions concerning changes in the situation as the displays were updated. Both response time and response accuracy scores were obtained. Half the participants viewing each set were males and half were females. All participants were screened to insure a lack of familiarity with the traditional symbols and for normal color vision and visual acuity.

Principal Findings:

- Accuracy of response to the two symbol sets did not differ.
- Male and female participants were equally accurate in reporting changes.
- Response time was significantly faster to the displays containing the experimental symbols.
- Females were both faster and less variable than males in responding to both the traditional and experimental symbol sets.

Utilization of Findings:

The finding that redundant coding improves response time should serve as a guide in further development of symbologies. Those responsible for personnel selection and classification should be able to make good use of the finding that females respond to information displays both more rapidly and with less variability than males.

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Chapter 1

INTRODUCTION AND BACKGROUND

Introduction

An earlier report by the present authors presented a review of the literature relevant to symbology for automated graphic displays.[1] It was concluded that the symbology currently employed by the Army in tactical displays is less than optimum for present day use. As a result, one of the recommendations made was for further investigation of alternative symbologies for their potential in facilitating information processing by users of tactical displays.

At the time the above referenced report was being prepared, the Combined Arms Concept Development Agency (CACDA) requested the TRADOC Combined Arms Test Activity (TCATA) to conduct a symbology comparison study employing the Command and Control Interactive Display Experimentation System (CCIDES). CCIDES utilizes a Cathode Ray Tube (CRT) display with four-color capability (red, orange, green, and yellow), and with a program capability for simultaneous display of both dynamic (military units, supply routes, etc.) and static (roads, towns, etc.) features of the battle area.

As a result of this development, the present authors, in conjunction with TCATA personnel, planned a study to compare four alternative symbologies. Human operator information-processing and decision-making functions were to be studied during the conduct of a rather lengthy battle scenario simulated on the CCIDES equipment. However, before the research could be conducted, a decision was made to transfer the CCIDES equipment to the European Theatre, making it unavailable for the proposed research.

As a result of this latter development, a more limited study was designed which could be completed within the time allotted and with the resources available. This study is described in Chapters 2 and 3 of this report.

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[1] P. W. Hemingway, A. L. Kubala, and G. D. Chastain. *Study of symbology for automated graphic displays*, HumRRO Final Report FR-WD-TX-78-8, May 1978 (ARI Technical Report, in process).

Background

Agreement on exactly what tasks should be performed by operators of tactical graphic display systems is far from perfect. However, there is general agreement that operators will perform tasks which involve the recognition and counting of various types of units, and noting the movement, removal, or addition of units in the battle area. Therefore, most of the research that has attempted to examine the "efficiency" of alternative symbologies has centered on these kinds of activities.

Easy recognition of symbols on a display is obviously important. However, Bowen, *et al.*[2] surveyed the literature in 1959 and found no definitive rules for constructing easily recognizable symbols for radar displays. These authors, therefore, attempted to find the rank-order discriminability of a set of 20 geometric symbols. Using varying degrees of degradation by noise, distortion and blur, they established subsets which would yield minimal confusion of forms. Increasing distortion and noise lowered performance significantly, but increasing blur alone did not. Ten symbols were found that were highly discriminable from one another under "good" conditions. However, it was recommended that no more than six be used under adverse conditions. The 10 symbols Bowen, *et al.* found most discriminable were a rectangle, a circle, a "Z," a cross, a half-circle, an oval, a triangle, a pentagon, a star, and an arrow. The triangle was number 13. However, Bowen, *et al.* indicated that it was easily discriminable so long as it was not in a set with the pentagon.

Vicino, *et al.*[3] examined the effects of different types of cuing on operator ability to determine changes in tactical situation displays. They prepared two sets of slides. Each slide in Set I depicted a tactical map display in which either 12, 18, or 24 military symbols were randomly placed. For each slide in Set I, there was a corresponding slide in Set II. However, on the Set II slides, either 2, 4, or 6 symbols had been added, removed, or repositioned.

Each of 48 subjects was shown a slide from Set I and asked to count and identify the unit symbols displayed (half of which were infantry, one-quarter artillery, one-sixth air defense, and one-twelfth engineer units). The subject was then briefly shown the corresponding slide from Set II, and, on a scaled-down paper print of the first slide, asked to note what changes had occurred. The control group had no aids of any

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[2] H. M. Bowen, J. Andreassi, S. Truax, and J. Orlansky. *Optimum symbols for radar displays,* ONR-0682(00), Office of Naval Research, Washington, D.C., September 1959.

[3] F. L. Vicino, R. S. Andrews, and S. Ringel. *Conspicuity coding of updated symbolic information,* Technical Research Note 152, Support System Research Laboratory, US Army Personnel Research Office, May 1965.

sort, while the three experimental groups were given either a hard copy of the Set II slide, shown a slide of Set II containing a single-cue code (N for new, M for moved, or R for Removed), or shown a slide from Set II containing a double-cue code (double lines around changed units, as well as the letter code). Two scores were computed for each individual: a Rate of Information Extraction score (based on the ratio of the number of changes correctly noted to total response time), and an Accuracy of Information Assimilation score (based on the ratio of the number of changes correctly noted to the sum of the number of changes correctly noted plus the sum of errors of ommission and commission). It was found that: (a) Increasing either the amount of information presented originally (12, 18, or 24 symbols) or in updating (2, 4, or 6 alterations) resulted in performance decrements; (b) Double-cue coding eliminated performance decrement due to increased information; (c) Double-cue coding improved extraction scores by 97%, and assimilation scores by 57% over unaided performance. Single-cue coding resulted in a 68% and 47% improvement, respectively. (d) Providing hard copy failed to improve extraction at all, and improved assimilation only slightly. (e) Both extraction and assimilation scores were highest when symbols had been removed, and lowest when symbols had been repositioned. (f) As the number of changes was increased, errors of omission increased more rapidly than errors of commission. The authors concluded that operators watching displays characterized by frequent or drastic updating need much better methods of keeping track of changes than were currently (1965) available.

Vicino and Ringel[4] conducted a study in which participants used updating information to reach a decision. The 37 participants viewed a series of slides depicting a series of tactical situations. The subjects were to determine in which of three sections the enemy was forming fastest for attack and which showed the most appropriate disposition (deployment) of forces. The development of each situation was depicted in either 7 or 14 slides, and the data on the slides were either in graphic or in alphanumeric form. The results were rather inconclusive. No differences were found as a function of updating rate nor between the graphic and alphanumeric formats. However, subjects did show a greater shift in confidence in their responses from slide to slide in the 7-slide condition. Also, regardless of the condition of presentation, the correct final decision tended to occur about three-quarters of the way through the series.

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[4] F. L. Vicino and S. Ringel. *Decision making with updated graphic vs. alpha-numeric information*, Technical Research Note 178, US Army Personnel Research Office, Washington, D.C., November 1965.

In addition to these studies involving updating (changing) situations, there are several studies of the use of color coding, a capability now available in CCIDES and other current CRT display systems. The use of color as a coding dimension has been studied rather extensively,[5] but only a few of these have utilized situations similar to the operation of a battlefield display system.

Smith[6] proposed that visual search time is a fundamental measure of the potential value of color coding of displays. Accordingly, Smith presented his subjects with targets consisting of one of five possible letters, three numerals, and a vector. Either 20, 60, or 100 items appeared in each of 180 displays, with half the displays in black and white, and the other half in colors. The five colors used were redundant with the five class-designator letters. The 12 subjects either searched for a particular target or counted the number of a particular class. As might be expected, both search time and counting errors increased with increasing density. Color had no effect if the subject was ignorant of its relevance. However, informing subjects in advance of the redundancy of color and letter codes resulted in a 65% reduction in search time, a 69% reduction in counting time, and a 76% reduction in counting errors.

Jones,[7] in a review of the literature, concluded that search time is decreased by the concomitant use of a partially redundant color code and a code set. That is, search time is reduced when the observer is aware of the redundancy. However, Jones also concluded that color coding is not suited for situations requiring rapid and precise identifications. Therefore, in choosing codes, the tasks required of the operator must be taken into account.

Smith and Thomas[8] examined the use of color as a <u>non</u>redundant code, and compared it with shape coding. They prepared displays which contained either 20, 60, or 100 symbols on a dark background. Each display

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[5] R. E. Christ. "Review and analysis of color coding research for visual displays," *Human Factors*, 1975, *17*(6), 542-570.

[6] S. L. Smith. "Color coding and visual search," *Journal of Experimental Psychology*, 1962, 434-440.

[7] M. R. Jones. "Color coding," *Human Factors*, 1962, *4*(4), 355-365.

[8] S. L. Smith and D. W. Thomas. "Color versus shape coding in information displays," *Journal of Applied Psychology*, 1964, *48*(3), 137-146.

contained five shapes and five colors, with each symbol appearing in any one of the five colors randomly chosen. Subjects counted the instances of each color and each shape on each display. Therefore, during the course of the study, they counted each display 10 times. A second set of displays contained all five shape symbols on each display, but contained only one of the five colors. A third set contained only one symbol per display, but all five colors. Colors were counted two to three times as rapidly as shapes. Fewer errors were made in counting colors and on lower density displays. Statistical analyses indicated that differences in counting time were attributable to display density, shape code, counting code (color or shape), and their interaction. The authors did not attempt to explain the interactions, but stated that some combinations apparently were effective in enhancing counting performance.

In a draft of a study Sidorsky[9] reports on the results of an investigation of the efficacy of color coding in tactical displays using a 19-inch CRT display. Forty subjects performed four tasks of increasing complexity, each building on the previous task. Color coding was used on three of the four code types to designate either unit size, unit type, or unit status. His results revealed that color used at the first level of analysis (unit type) facilitates information extraction; if used at other levels, it is no better, and in some cases worse than standard military symbology.

The literature cited is but a small sample of the voluminous literature that has relevance to this present effort. However, it is representative of both the types of investigations conducted and the results obtained. To summarize very simplistically, both speed and accuracy of interpretation are enhanced when symbols are easily discriminable and when redundant coding is employed. In view of these findings, a scaled-down version of the original study planned for the CCIDES facility was designed. Two alternative symbol sets were prepared, both showing the same information (changes in location and addition or deletion of units). One symbol set consisted of standard military symbols.[10] The other set was selected from the 20 symbol set used by Bowen, *et al.*[11] The particular symbols employed were chosen on the basis of informal discussions with CCIDES personnel and other military personnel. Four symbols were chosen as conveying unit type or

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[9] R. C. Sidorsky. *Colored symbols in tactical displays: Help or hindrance?* Army Research Institute, Washington, D.C., June 1976, Draft.

[10] US Department of the Army, Washington, D.C. Field Manual 20-30, *Military symbols*, 1970.

[11] Bowen, *et al.*, *op. cit.*

function fairly well. The arrow was heavily favored as the artillery symbol, representing flight and motion. The square was nearly as favored for armor, because of its appearance of massiveness and weight. The choice for mechanized infantry was not as clear, but the diamond "won" by a slight majority. (This might be due to the fact that it is the symbol for an armored personnel carrier.) The selection of an appropriate infantry symbol was the most difficult, the majority favoring the triangle until the similarity of it to the head of the arrow was noted when both were displayed on the CRT. Thus, the circle was chosen for its lack of confusion with the other choices, and, perhaps, because it is the Soviet symbol for infantry. Assignment of color was simply arbitrary, except the red for artillery, which was based on the association of red with fire. (Several of the military personnel made comments such as--"What do you say when you want to shoot a cannon?" "FIRE!") Color was intended as a redundant coding dimension for the alternative symbols, under the hypothesis that this would decrease subject response time, but not increase accuracy of response.[12] The choice of the four colors (red, green, blue, and yellow) was based on Osgood's[13] finding of those four colors as being maximally discriminable. In addition, it was hypothesized that accuracy scores would be lowest for movement identification, intermediate for additions, and highest for removals.[14]

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[12] M. Munns. *Some effects of display symbol variation upon operator performance in aircraft interception*, NADS-MR-617, Naval Air Development Center, November 1967.

[13] C. E. Osgood. *Method and theory in experimental psychology*, Fair Lawn, New Jersey: Oxford University Press, 1953.

[14] Vicino and Ringel, *op. cit.*

Chapter 2

DESIGN AND PROCEDURE

Displays

This experiment was designed to test the differences in response time and accuracy of response by naive subjects to two sequences of four displays representing a changing battleground situation. One set of displays used standard military symbols for four types of units (artillery, armor, infantry, and mechanized infantry). The other set used alternate symbols, as described in the previous chapter, for these same units with a redundant color code (red arrow for artillery, blue square for armor, yellow circle for infantry, and green diamond for mechanized infantry).

Two sets of four slides, one for each display in each symbol set, were prepared by the personnel of the HumRRO unit at Fort Bliss, Texas. The slides represented a changing battlefield situation which is briefly described in Table 2-1. Figure 2-1 shows the first slide from each set.

Standard military usage was used to identify friendly and enemy forces; red for enemy, green for friendly on Set I (CCIDES convention) and single line symbols for friendly and double-line symbols for enemy on Set II.

Subjects

Subjects were paid volunteers from the student body of Central Texas College, Killeen, Texas. Subjects were screened for lack of military background to insure a lack of familiarity with the standard symbology. They were also tested for visual acuity employing a Bausch and Lomb Double Broken Ring Acuity Test, #713599-101ND. Personnel with 20/40 visual acuity or better were accepted. Prospective participants were also tested to insure that they had normal color vision. This was accomplished using the Dvorine Pseudo-Isochromatic Plates, 2nd Edition (Harcourt, Brace, & World, Inc., New York, 1963) under a 100-watt Blue-Daylight lamp, at a distance of 22 inches from eye to plate.

Procedure

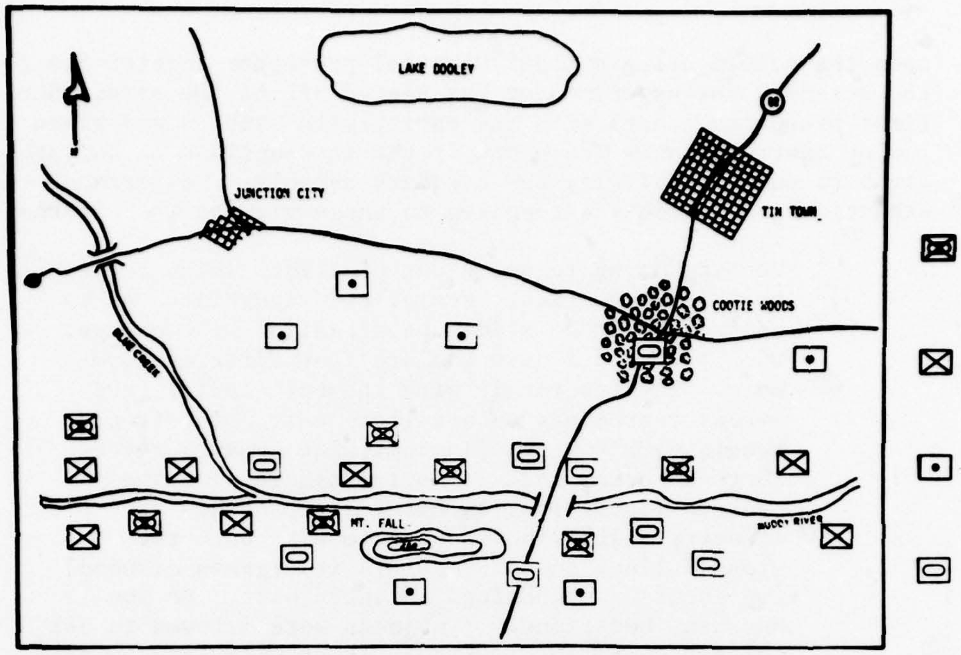
Subjects were tested individually in a low-illumination room (<10 lumens) seated 8 feet from the projection screen, giving a minimum of 40 minutes of arc subtended by any one symbol. The slides were projected

Table 2-1. Four-Step Battlefield Simulation (enemy forces north of river, friendly forces south of river)

	Number of Units: Friend	Number of Units: Foe
Slide I (Training)		
Type of Unit		
Artillery	2	4
Armor	4	4
Infantry	3	4
Mechanized Infantry	3	4
	12	16
Slide II (Test)		
Artillery	2 (0 added)	4 (1 moved)
Armor	6 (2 added)	4 (1 moved)
Infantry	3 (0 added)	4 (1 moved)
Mechanized Infantry	5 (2 added)	4 (2 moved)
	16	16
Slide III (Test)		
Artillery	2 (0 removed)	3 (1 removed)
Armor	5 (1 removed)	4 (0 removed)
Infantry	2 (1 removed)	2 (2 removed)
Mechanized Infantry	3 (2 removed)	3 (1 removed)
	12	12
Slide IV (Test)		
Artillery	4 (2 added)	2 (1 removed)
Armor	6 (1 added)	4 (0 removed)
Infantry	4 (2 added)	2 (0 removed)
Mechanized Infantry	4 (1 added)	2 (1 removed)
	18	10

Set I

Standard Symbology



Set II

Alternate Symbology

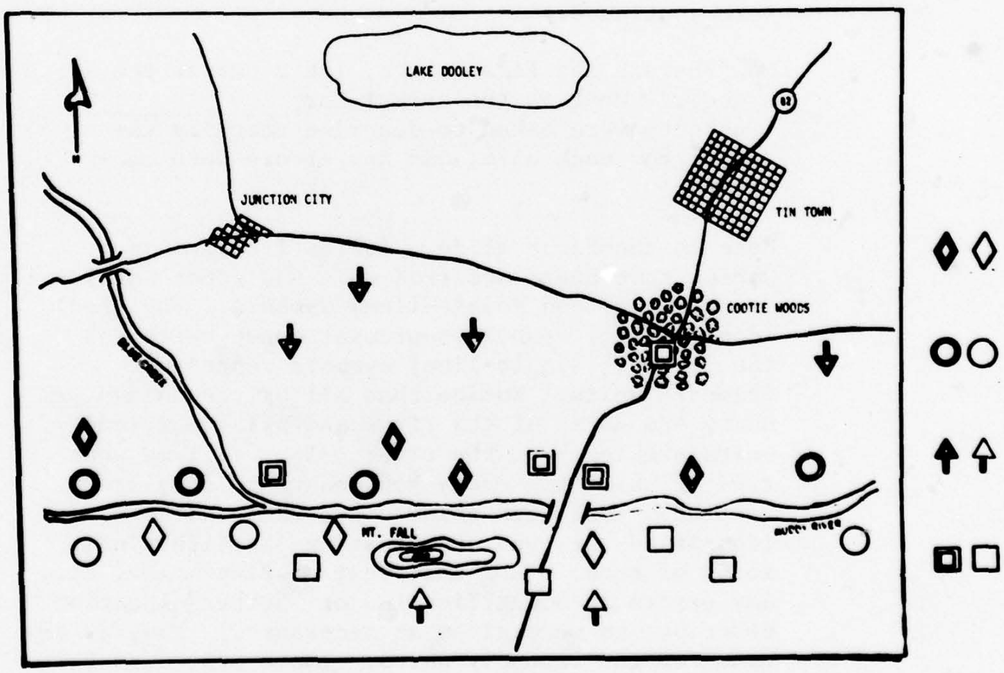


Figure 2-1. The first slide from the two symbol sets.

upon the screen using a Kodak Carousel projector located 8.5 feet from the screen. The experimenter was seated off to the side. Subjects were first presented a card with the appropriate symbols and given the following instructions. The parts of the instructions in parentheses were given to subjects viewing the standard symbols, the parts of the instructions in brackets were given to those viewing the alternate set.

> You are going to see a set of slides which represent a hypothetical battlefield situation. As we go from slide to slide the situation will change. Upon the card I gave you are four different symbols. The (rectangle with the ball in it) [red arrow] represents an artillery unit. The (rectangle with the oval in it) [blue square] represents an armor unit. The (rectangle with the crossed lines) [yellow circle] represents an infantry unit. The (rectangle with both the crossed lines and the oval in it) [green diamond] represents a mechanized infantry unit. Do you have any questions? (Subjects were allowed to ask for explanations of what an armor unit, etc., was, repeated definition of the symbols, etc., as much as desired. When through inquiring, the directions were continued.)
>
> Now, before the first slide, let's review the symbols. What is the symbol for ____________? (Subjects were asked to describe verbally the symbol for each unit, and any errors were corrected.)
>
> Here is the first slide. (Slide I turned on.) Notice that there are (red unit and green unit) [single-line and double-line] symbols. The (red) [double-line] symbols represent enemy units and the (green) [single-line] symbols represent friendly units. Notice that all of the enemy units are north of the river and all the friendly units are south of the river. Now, tell me what type of units the enemy has and where they are located. (Subjects pointed out each unit and identified the type and location--artillery unit south of road, armor unit west of Blue Creek, etc. Any errors in identification or "better" location descriptions were given as necessary.) Now, do the same for the friendly units. (Same procedure followed.) (Slide OFF.)

> Fine! Now, I want you to answer some questions. I am going to turn the same slide on, and I want you to answer each question as quickly as possible.

(The following eight questions were asked, but in a different random order for each subject.)

1. How many enemy artillery units are there?
2. How many friendly artillery units?
3. Which side has the most armor units?
4. How many armor units does each side have?
5. How many friendly infantry units are there?
6. How many enemy infantry units are there?
7. Who has the most mechanized infantry units?
8. How many mechanized infantry units does each side have?

(Slide OFF.)

Again, any errors were noted and the subject was informed. At this time, the subject was informed of the remaining tasks.

> You will have 30 seconds to look at this slide again. You will then see a new slide and be asked questions as to any changes in the number and location of units on both sides. Please answer as quickly and accurately as possible.

The first slide was displayed for 30 seconds and then Slide II was displayed. The subject was allowed to view Slide II for 10 seconds and then asked the following questions (again, a different random order of questions was employed for each subject). Response time to each question was recorded in tenths of seconds from end of question to end of answer, and the answer was recorded.

Slide II Questions:

1. How many, if any, enemy artillery units moved?
2. How many, if any, enemy armor units moved?
3. How many, if any, enemy infantry units moved?
4. How many, if any, enemy mechanized infantry units moved?
5. How many, if any, friendly artillery units were lost or added?
6. How many, if any, friendly armor units were lost or added?
7. How many, if any, friendly infantry units were lost or added?
8. How many, if any, friendly mechanized infantry units were lost or added?

After the last question, subjects were told:

You will have 30 more seconds to study this slide.
Then a new slide will come on and you will be
asked questions about changes from this slide.

Slide III Questions: (Given in different random orders.)

1. How many, if any, enemy artillery units were added or removed?
2. How many, if any, enemy armor units were added or removed?
3. How many, if any, enemy infantry units were added or removed?
4. How many, if any, enemy mechanized infantry units were added or removed?
5. How many, if any, friendly artillery units were added or removed?
6. How many, if any, friendly armor units were added or removed?
7. How many, if any, friendly infantry units were added or removed?
8. How many, if any, friendly mechanized infantry units were added or removed?

Again, response times and answers were recorded. After the last question, subjects were again given 30 additional seconds, then Slide IV was presented and the same questions were asked as on Slide III.

Thus, for each subject, 24 responses and response times were recorded. Thirty-two subjects were tested during a three-day period, with the two symbol sets given alternately, insofar as possible, but this was varied as necessary in order to balance the number of subjects of each sex taking each form. At the end of the test period, subjects were thanked for their cooperation and requested not to discuss the experiment with other subjects until after the end of testing.

Chapter 3

RESULTS AND ANALYSES

The verbal response and response time for each question were recorded on an answer sheet for each subject. All data were then transferred to master sheets, one set for accuracy scores and one set for response times. The data were analyzed in several ways in order to examine the effects of the two symbol sets, the particular symbols for different units, and the type of question asked.

Table 3-1 presents the summary statistics for the accuracy scores and for the response times. These figures show very little mean difference between the two symbol sets or the sexes on overall accuracy, but fairly pronounced differences in response times and in variability of response time for both symbol sets and sex.

Table 3-1. Summary Statistics of Symbology Study

	Symbol Set I		Symbol Set II	
	Males (n = 8)	Females (n = 8)	Males (n = 8)	Females (n = 8)
a. Accuracy of Scores (24 items)				
Mean	12.38	14.00	14.00	14.00
Standard Deviation	8.82	6.32	9.17	8.49
b. Average Response Time per Item (in seconds)				
Mean	9.00	6.53	6.70	5.23
Standard Deviation	11.57	2.41	7.49	3.79

In order to determine the more detailed effects of symbol sets and of sex, the 24 items were divided into six blocks. In each block, an individual's score is the sum of the correct responses to a particular set of questions. The scores represented in each block are shown below:

Block 1: Response to questions on enemy movement (Slide II).

Block 2: Responses to questions on friendly unit losses and gains (Slide II).

Block 3: Responses to questions on enemy unit losses and gains (Slide III).

Block 4: Responses to questions on friendly unit losses and gains (Slide III).

Block 5: Responses to questions on enemy unit losses and gains (Slide IV).

Block 6: Responses to questions on friendly unit losses and gains (Slide IV).

Obviously, these blocks do not represent a quantitative continuum. Rather, they represent the results of two types of information-processing required by the participants: (a) the detection of movement, and (b) the detection of losses and gains. It was felt important to distinguish between these types of questions as Vicino, *et al.*[1] found that the repositioning of symbols was more difficult to detect than the removal of symbols.

Scores on response times to the questions were also divided into blocks as described above. Each individual's score is the sum of the response times to the questions indicated. Both sets of data were analyzed by analysis of variance. The results of these analyses are presented in Tables 3-2 and 3-3. As expected from the summary statistics in Table 3-1, the analysis of the accuracy scores showed no significant effects between sets or between sexes. However, the within-effects analysis revealed a *very* strong blocks-effect, due almost entirely to the low scores on Block 1, the movement questions. As hypothesized, detecting unit movement is much more difficult than detecting the addition or subtraction of units. No significant difference in accuracy was found between scores on units added blocks and units subtracted blocks ($M_{Add} = 19.9$ and $M_{Loss} = 19.1$).[2]

The two significant interactions of block-by-symbol set and block-by-sex are illustrated in Figure 3-1. The symbol set interaction (solid lines vs dotted lines) reveal a tendency for Set I scores to remain fairly flat after the first block, while Set II scores rise on Blocks 2

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[1] F. L. Vicino, R. S. Andrews, and S. Ringel. *Conspicuity coding of updated symbolic information,* Technical Research Note 152, Support Systems Research Laboratory, US Army Personnel Research Office, Washington, D.C., May 1965.

[2] Although participants were asked to enumerate both gains and losses in each question, in all cases one side to the conflict showed either gains or losses, but not both (see Table 2-1). Therefore, Blocks 2 and 6 involved counting additions, while Blocks 3, 4, and 5 involved counting losses.

Table 3-2. Analysis of Variance of Accuracy Scores by Blocks

Source	SS	df	MS	F	p
Total	233.45	191			
Total Between	48.28	31			
Symbol Sets	.88	1	.88	<1	---
Sex	.88	1	.88	<1	---
Sex x Set	.88	1	.88	<1	---
$Error_b$	45.64	28	1.63		
Total Within	185.17	160			
Blocks	31.92	5	6.38	6.98	<.001
Blocks x Set	10.21	5	2.04	2.23	<.05
Block x Sex	12.46	5	2.49	2.73	<.025
Block x Set x Sex	2.60	5	.52		
$Error_w$	127.98	140	.914		

Table 3-3. Analysis of Variance of Response Time Scores by Blocks (in seconds)

Source	SS	df	MS	F	p
Total	187,930	191			
Total Between	26,134	31			
Symbol Sets	2586.02	1	2586.02	4.99	<.05
Sex	3104.09	1	3104.09	5.99	<.025
Sets x Sex	229.68	1	229.68	<1.00	
$Error_b$	14504.09	28	518.00		
Total Within	15714.67	160			
Blocks	5584.17	5	1116.93	18.83	<.001
Blocks x Sets	810.23	5	162.05	2.73	<.025
Blocks x Sex	161.41	5	32.28	<1.00	---
Blocks x Sets x Sex	862.32	5	172.46	2.91	<.025
$Error_w$	8296.54	140	59.26		

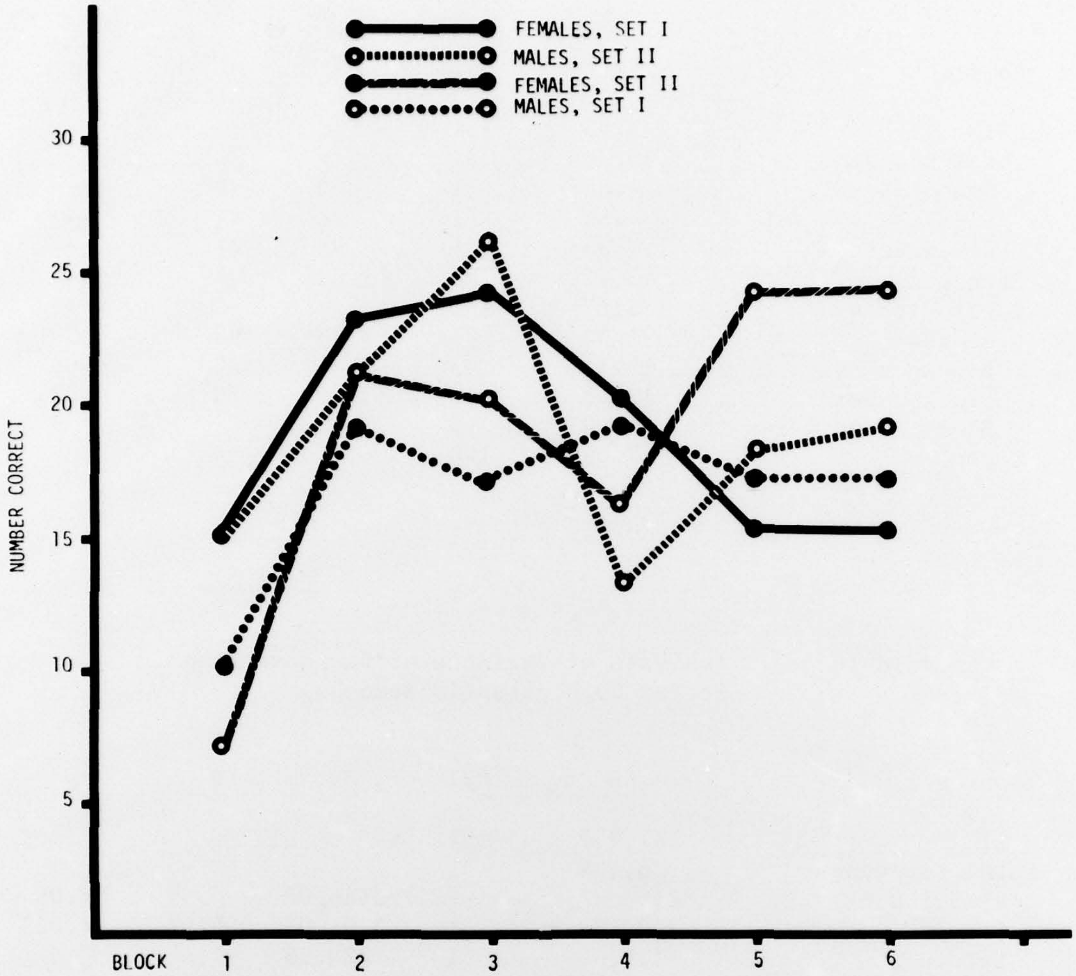

Figure 3-1. Group accuracy scores by block.

and 3; fall on Block 4, then rise again on Blocks 5 and 6. The block-by-sex interaction (dots vs circles) show the male subjects' scores remaining fairly flat after the first block, while female subjects' scores rise, fall, and then level out on Blocks 5 and 6. No logical interpretation of these interactions could be found. Note, for example, that Blocks 4 and 5 both deal with the counting of losses. Losses were apparently easier to count on Set I (standard symbology) in Slide III, while they were apparently easier to count on Set II (experimental symbology) in Slide IV. Any attempt at explanation would be purely speculative, and does not seem warranted at this time.

In the analysis (Table 3-3) of response time-by-block, significant effects are found both as between-effects and as within-effects. For the between-effects, both the two symbol sets and the two sexes were found to have significantly different total response times, with responses being significantly slower on Symbol Set I than on Symbol Set II, and significantly slower for male subjects than for female subjects. The difference between the two symbol sets is as hypothesized, the double coding (color plus shape) on Set II seeming to allow faster (but no more accurate) response than the single coding (shape) on Set I.

The sex difference is not surprising, as female subjects have typically been observed to be both faster and more consistent (less variable) than males on perceptual tasks.[3,4] The variance difference between males and females was also significant ($F = 9.18$, $p < .01$), with the males showing a much greater variability in response time, particularly on Symbol Set I (see Table 3-1). This was partly due to one male subject who had response times ranging from a low of 5.4 seconds on one question to as high as 36.2 seconds on another. However, the majority of the males were individually more variable than the female subjects.

Table 3-3 also shows a very highly significant blocks-effect, again primarily due to Block 1, the movement questions, where all groups had quite high response times, but as Figure 3-2 illustrates, between-group differences were greater on the other blocks, especially Block 6. The significant blocks-by-symbol set interaction and the significant three-way interaction among blocks, sets, and sex, also illustrated on Figure 3-2, are difficult to interpret. The blocks-by-set interaction results from the fact that the difference between reponse times increases with each succeeding slide. It can also be noted in Figure 3-2 that response

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[3] C. E. Osgood. *Method and theory in experimental psychology*, Fair Lawn, New Jersey: Oxford University Press, 1953.

[4] T. N. Cornsweet. *Visual perception*, New York: Academic Press, 1970.

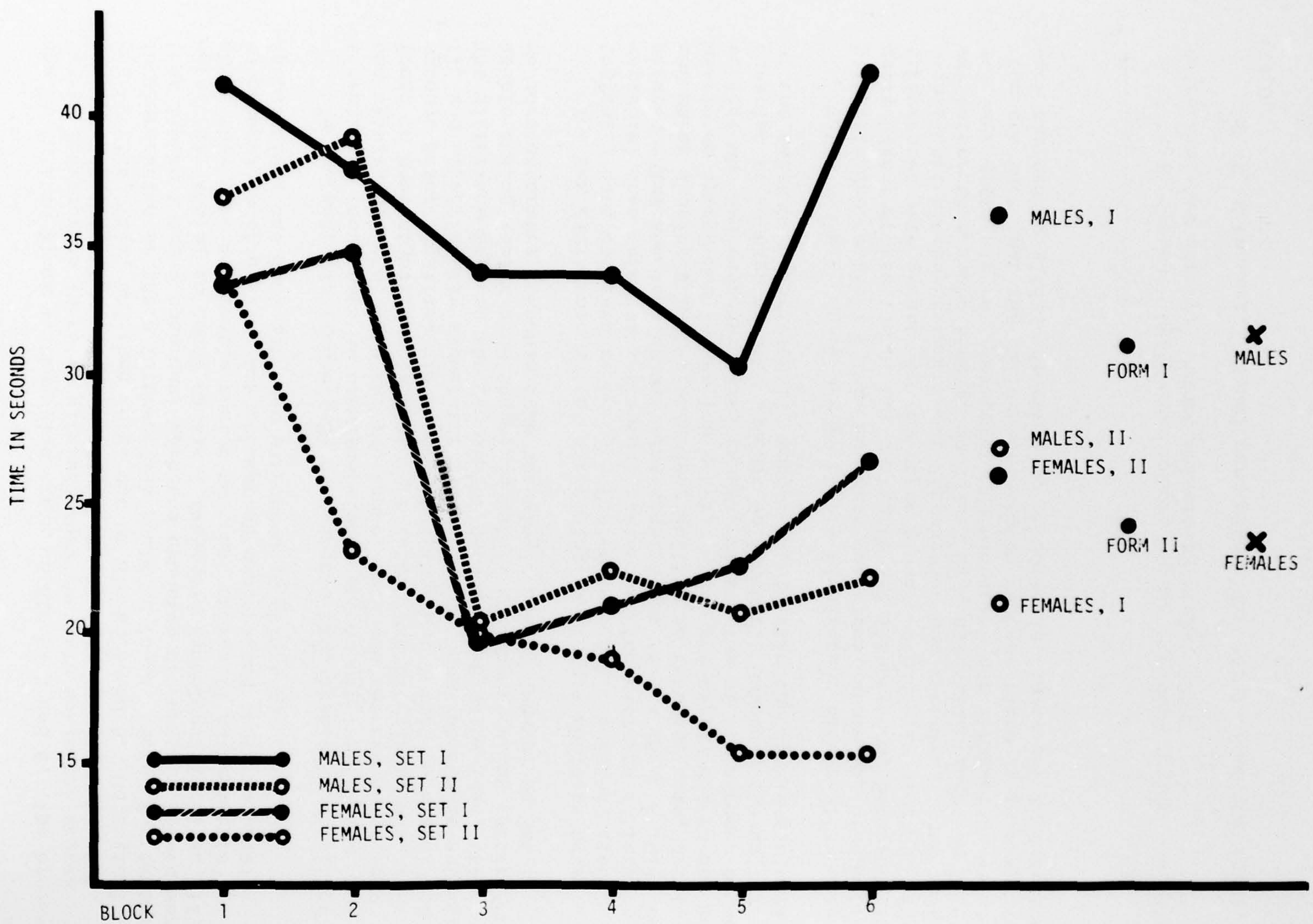

Figure 3-2. Group average response time per block.

times, in general, decrease considerably after Slide II. There is a slightly increased response time in Block 6 over Block 5. However, the subjects were required to count six changes in Block 6 compared to three in Block 5. In brief, the general decrease in response time could be interpreted as a learning or practice effect. If so, the blocks-by-symbol set interaction would indicate that learning is faster with the experimental symbols than with the standard symbols.

In summary, it appears that the sexes are equally accurate in determining changes in displays, and that accuracy is not influenced by symbol type--at least for the two types studied. However, females respond more rapidly than males, and both sexes respond more rapidly to the experimental symbols than the standard symbols.

The significant blocks-effect found in both analyses may, at least in part, be an artifact of the order in which questions were asked and the difficulty of the task in each slide. The response times in Block 2 are notably longer than for the remaining blocks. This was true even though only four changes were made in this slide compared to six changes in Slide IV (Block 6). The times recorded for this block represent the first series of questions on additions or removals that the subjects received. Therefore, they may have been slower in responding. In other words, the faster responses in later blocks may have resulted from a practice or learning effect as discussed earlier. The same reasoning could be applied to the longer response time to the questions on repositioning represented in Block 1. These were the first questions the participants received. However, the gross difference in the accuracy scores for this block argues against this being the case. Both males and females obviously had difficulty in trying to determine what units had been repositioned as accuracy was very poor. Therefore, it seems reasonable that they would take longer to respond to these questions.

Analyses of Unit Symbols

The data described above were combined in a different fashion in order to analyze for differences between response time and reporting accuracy between the symbols for the four types of units. There were six questions asked concerning each type of unit, so each individual had four accuracy scores, one for each unit type, based on his or her responses to the six questions. The data on response times were combined in the same manner.

The data were again analyzed by analysis of variance. Tables 3-4 and 3-5 summarize the results of these analyses. Table 3-4 reveals that reporting accuracy did not differ between the sexes or between the two symbol sets. However, the within-analysis shows a highly significant difference between symbols, with no significant interactions. This difference is due almost entirely to the artillery symbols, with the

Table 3-4. Analysis of Variance of Accuracy Scores by Type of Unit Symbol

Source	SS	df	MS	F	p
Total	254.66	127	--		
Total Between	72.43	31	--		
Symbol Sets	1.32	1	1.32	<1	--
Sex	1.32	1	1.32	<1	--
Sets x Sex	1.32	1	1.32	<1	--
$Error_b$	65.83	28	2.35		
Total Within	182.25	96	--	--	
Unit Type	30.09	3	10.03	6.23	<.001
Type x Set	4.46	3	1.49	<1	
Type x Sex	10.59	3	3.53	2.21	n.s.
Type x Set x Sex	1.71	3	.57	<1	
$Error_w$	135.41	84	1.61	--	

Table 3-5. Analysis of Variance of Response Times by Unit Symbol

Source	SS	df	MS	F	p
Total	48417.5	127			
Total Between	39216.5	31			
Symbol Sets	3916.125	1		36.26	<.001
Sex	4728.78	1		43.78	<.001
Sets x Sex	331.53	1		3.07	n.s.
$Error_b$	3024.01	28			
Total Within	9201	96			
Unit Symbols Type	883.06	3	294.35	3.38	<.025
Type x Set	379.32	3	126.44	1.45	n.s.
Type x Sex	202.78	3	67.59	<1.0	
Type x Set x Sex	411.65	3	137.22	1.57	n.s.
$Error_w$	7324.19	84	87.19		

mean accuracy score per subject of 4.19 being significantly higher than those for the other three symbols (3.38 for armor, 3.12 for infantry, 2.91 for mechanized infantry), which do not differ significantly from one another. Thus, it would appear that, in this study, either artillery symbol is perceived more accurately than any of the other symbols in either set. However, this may be more a function of location than of symbol. Due to the nature of the battlefield displays, the artillery units tended to be further back (on both sides) from the front lines than the other units, thus perhaps easier to locate and mentally compare to prior displays than the other types of units.

In Table 3-5, both set and sex (but not their interaction) are very highly significant, with response time being over 20% longer for Set I symbols than for Set II symbols, and similarly longer for males than for females.

The only significant within-measure is by type of symbol, again with the artillery symbol having a significantly lower response time than the others which were not different from one another. Again, this may be due to the same ease of locating and comparing discussed in terms of the accuracy scores.

Other Analyses

Having analyzed these data separately for accuracy and response time, the question arises as to their independence. Therefore, a product-moment correlation was obtained between total number of items correct and total response time. The obtained r was -.27 ($n = 32$, $.10 > p > .05$), indicating a slight tendency for those with higher accuracy scores to also respond more quickly (lower response time). However, inspection of the data revealed that even this marginal correlation was primarily due to two cases, one female who was both very accurate and very quick-responding, and one male who was very slow and quite inaccurate. These findings make it difficult to hypothesize any meaningful relation between speed and accuracy, and, therefore, it is felt that they should be treated as substantially independent measures.

The accuracy of response to the different types of changes (movement, units added, units removed) was also examined. Table 3-6 summarizes the proportion of correct responses to each type of change question. Proportions are used to correct for the different number of questions concerning each type of change (4 on movement, 8 on units added, 12 on units removed). It is quite clear from the first row why the significant blocks-by-sex interaction in the first analysis of variance (Table 3-2) was obtained. Why females were more accurate on Symbol Set I and males were more accurate on Symbol Set II does not appear to have any logical explanation.

Table 3-6. Proportion of Change Items Answered Correctly

Change	Symbol Set I Male	Symbol Set I Female	Symbol Set II Male	Symbol Set II Female
Movement (1/16)	.3125	.4688	.4688	.2188
Added (2/6)	.5625	.5938	.6250	.7031
Removed (3/6)	.5312	.6146	.5938	.6250
TOTAL	.5156	.5833	.5833	.5833

There also does not appear to be any substantiation for the part of the hypothesis that additions would be less accurately reported than removals. In fact, they are slightly more accuratedly reported (62% to 57%), though not significantly so.

Summary of Findings

To summarize these analyses briefly, it appears from the overall results that there is no significant difference in the accuracy of observing changes between the two symbol sets used in this study, or between male and female subjects. There is, however, a very significant difference in accuracy of reporting by type of unit symbol, with the artillery unit symbols on both symbol sets being the most accurately reported, while the other three are not different from one another and are less accurately reported. As noted, this may be due (partially or entirely) to their location "away" from the more congested areas of unit concentration.

The results of the analyses on response time appear to clearly support the hypothesis that use of color as a fully redundant code to easily discriminable symbols does facilitate the speed with which symbols can be located, but not the accuracy with which changes can be reported.

The finding that females are both faster and less variable in response time than males is not unexpected from prior psychological sex-difference studies in perception, and suggests that female military personnel might be preferred for tasks requiring reporting of displayed information of any sort.

Overall, it would seem that this study, with its inherent limitations, does not answer too many questions about symbology in general, but does suggest that further research might be profitable on the use of color coding combined with a clearly discriminable graphic symbol set.

Chapter 4

IMPLICATIONS

Reponses to displays employing the experimental symbology were more rapid but no more accurate than responses to displays containing the standard symbology. Unfortunately, the data do not permit an evaluation of the separate contributions of shape and color to this result. Had the CCIDES equipment been available for the conduct of this research, it would have been possible to compare the standard with the experimental symbol set, both with and without the redundant color coding. With the loss of the CCIDES equipment, neither the resources nor the remaining time was sufficient to allow this more complete comparison. Therefore, additional research is needed to separate the contributions of shape and color to determine whether the use of color is worth the additional cost that would be incurred in developing and fielding the display equipment.

The data available indicate no difference in the ability of operators to detect additions or removals from a display. However, had a longer scenario been employed, a different result *might* have been obtained. The results, in keeping with other findings reported in the literature, do indicate that movement is more difficult to detect than other types of changes. Further work is apparently needed in devising aids for operators in detecting movement in updated displays.

Perhaps the main contribution of this effort is the finding that females respond both more rapidly and with less variability than males. While this result is also in keeping with general findings concerning sex differences in perceptual tasks, *so far as is known*, this is the only research accomplished which compared the sexes on information-processing employing tactical displays. Recently, more and more MOS have been opened to women. Women are still not allowed to participate directly in combat, but exactly which jobs are combat jobs has not been finally determined. In the future, women might be allowed to operate tactical display systems away from the frontlines. This research indicates that they may be superior to males in this role. Therefore, it is recommended that an attempt be made to replicate this finding.

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1 US Dept of Justice, DC, ATTN: Drug Enforce Admin
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1 Mil and Air Attache, Austrian Embassy
1 Centre de Recherche Des Facteurs, Humaine de la Defense Nationale, Brussels
2 Canadian Joint Staff Washington
1 C/Air Staff, Royal Canadian AF, ATTN: Pers Std Anal Br
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1 Ministeris van Defensie, DOOP/KL Afd Sociaal Psychologische Zaken, The Hague, Netherlands